B-tagged jets at sPHENIX

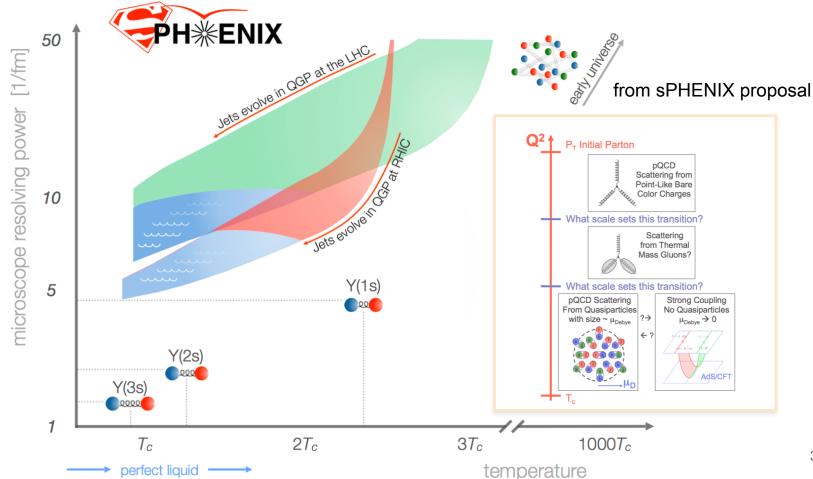
Sookhyun Lee

Aug. 15 2016 at LANL

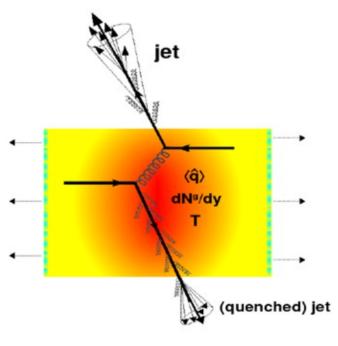
Outline

- Motivation Jets at sPHENIX
- Jets and parton-medium interaction
- sPHENIX detectors
- MAPS technology and tests
- Vertexing and tracking
- B-jet tagging Methods
- Future works

Jets are ideal hard probes into the QGP at sPHENIX

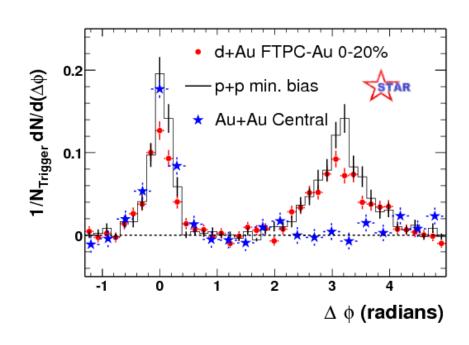


Jet quenching at RHIC



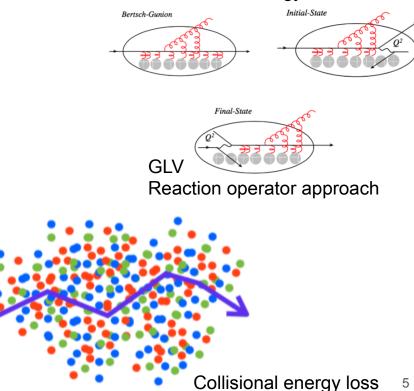
Jet quenching (Bjorken, 1982)

 $4 < p_T^{trig} < 6 \text{ GeV/c}$ $p_T^{assoc} > 2 \text{ GeV/c}$



Jet quenching and Parton-Medium interaction

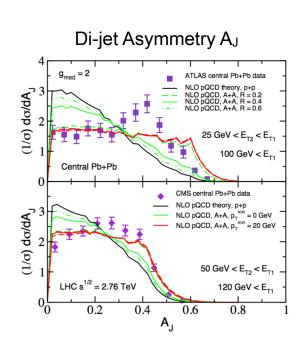
- Radiative energy loss was believed, for a long time, to be the dominant parton energy loss mechanism in medium.
- Another mechanism, collisional energy loss is being studied as the other main contributor
- Theoretical models are available to quantitatively describe each mechanism. (Coleman-Smith at el, Liao&Shuryak, Vitev at el. etc.)



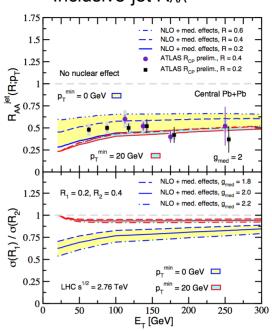
Radiative energy loss

Jets and Parton-Medium interaction

- LHC has shown results of Di-jet asymmetry and inclusive jet profile measurements to test models.
- Jets are perfect observables to model the coupling of the medium and its origin.

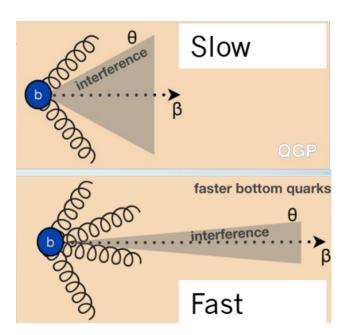






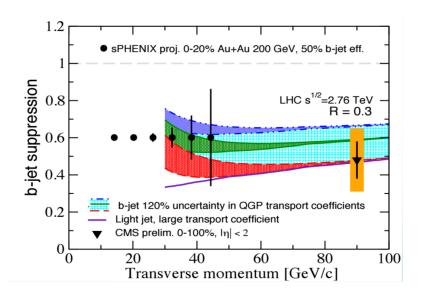
Heavy quark jets and collisional energy loss

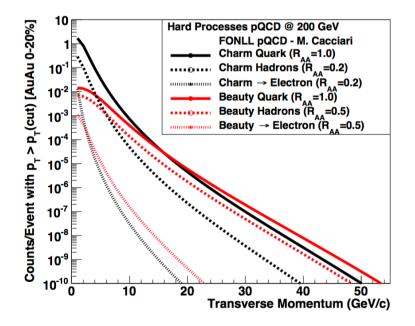
- Heavy quarks are most sensitive to collisional energy loss due to their suppressed radiative energy loss.
- Measurements have been made at RHIC of semi-leptonic decay from D and B mesons.
- Fully reconstructed heavy-flavor tagged jets with various range of energy and radius are crucial to further disentangle parton-medium interaction mechanisms.

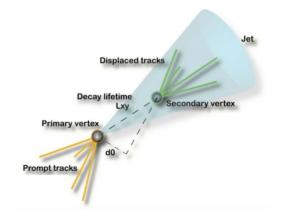


B - Jets @ sPHENIX

- New probe at RHIC
- Radiative vs. collisional energy loss
- Extend models to lower p_T

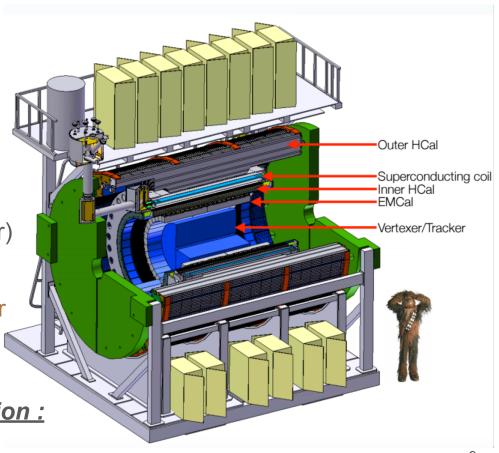






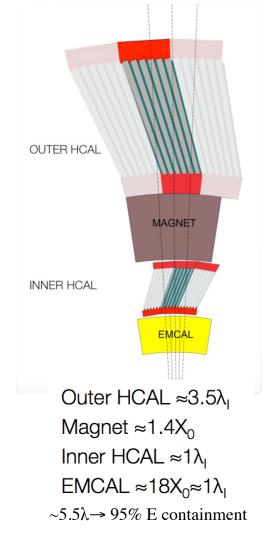
sPHENIX detectors

- Full and uniform acceptance with $0 < \phi < 2\pi$ and $-1 < \eta < 1$
- Outer/Inner Hadronic CALorimeter
- Superconducting solenoid (from BaBar)
 2.8 m radius, 3.8 m long, 1.5 T
- Compact Electro-Magnetic Calorimeter
- Vertexer/Tracker
- Requirements for b-jet reconstruction : DCA < 100um, electron ID.



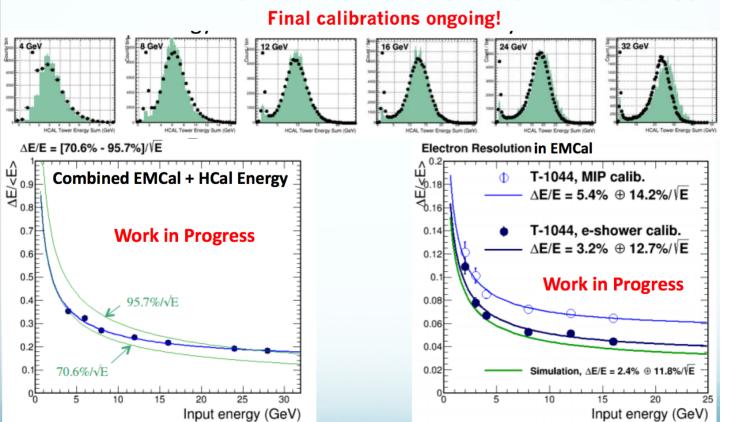
Calorimeters reference design

- Outer/Inner Hadronic CALorimeter
- Steel and scintillating tiles + wavelength shifting fiber
- $\triangle \eta \times \triangle \phi \sim 0.1 \times 0.1$
- σ_E / E < 100/120/150% / \sqrt{E} (single particle, jet in pp, jet in AuAu)
- Readout: silicon PMTs, work in magnetic field
- Compact Electro-Magnetic Calorimeter
- Tungsten + Scintillating fiber
- $\triangle \eta \times \triangle \phi \sim 0.025 \times 0.025$
- σ_E / E < 15% / √E (single particle, photon)





Preview of Test Beam Results



- Simulation shows good agreement with early data results
- Results fall within required performance

Slide taken from R.Reed talk given at RHIC Users Mtg.

Tracking detectors reference design

• Current default configuration :

MAPS (vertexer) and TPC (tracker)

Intermediate tracker under consideration.

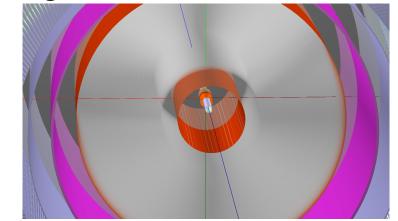
Monolithic Active pixel sensor (MAPS):

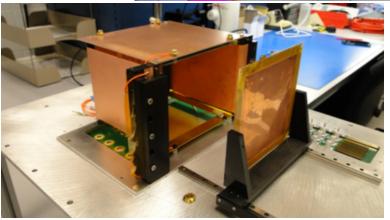
Imported from ALICE ITS

3 layers very close to IP (2.3, 3.2, 3.9 cm)

• Time Projection Chamber (TPC) :

Compact TPC with GEM readout. ~60 layers.



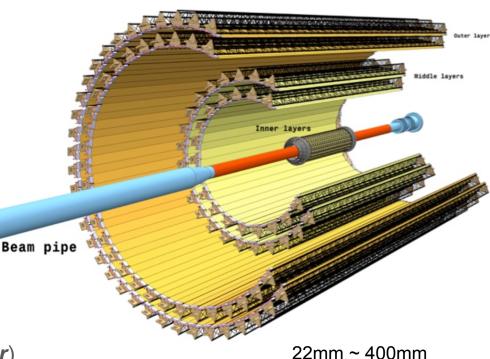


ITS upgrades to MAPS at CERN ALICE

 Aimed at heavy flavor measurements, therefore excellent impact parameter resolution and momentum resolution required.

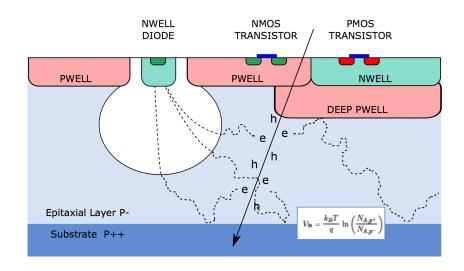
 Replace current 3-types (pixel, drift and strip) tracking detectors with *pixels* only.
 Size 30um x 30um. Spatial resolution ~5um.

Get closer to IP with 7 layer configuration.
 Reduced silicon material budget for inner layers (350um -> 50um, 0.3% X₀ per layer)



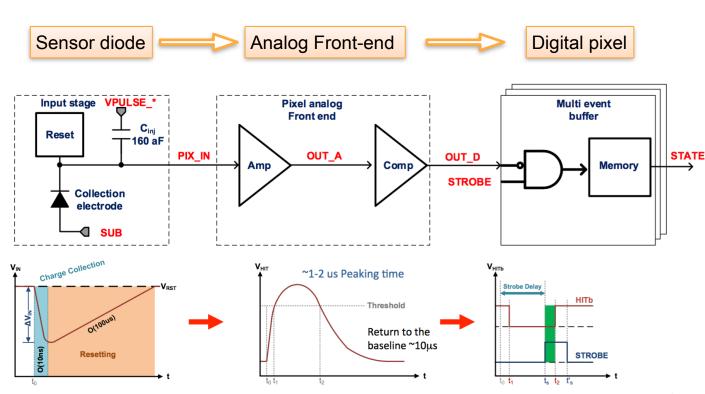
Monolithic Active Pixels Sensors (MAPS)

- 0.18um CMOS technology of TowerJazz
- high noise immunity
- high density/low power consumption (35 mW/cm²)
- Radiation hardness
 - ~2.7 Mrad (~1.7x10¹³ 1MeV n_{eq}/cm^2)
- High-speed (>100kHz) readout
 - binary hit info without PID (dE/dx)

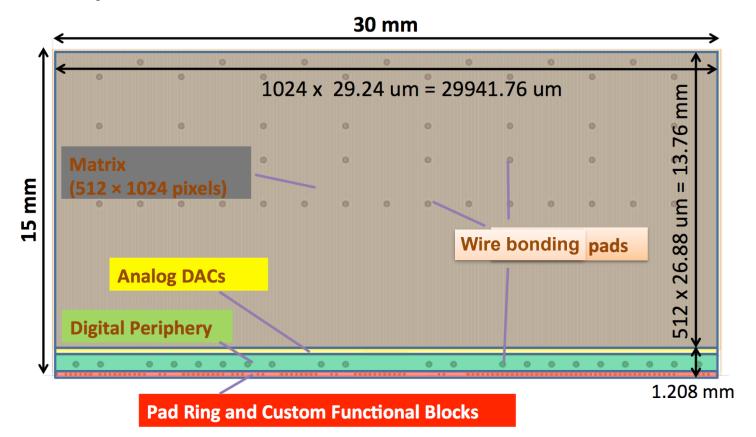


Operation principles of MAPS sensors

- In-pixel
- amplification
- discrimination
- hit-buffer
- In-matrixsparsification



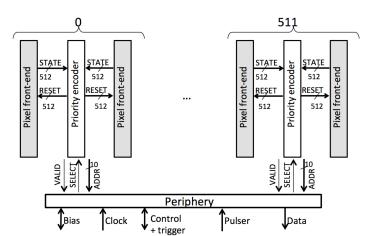
Chip floorpan

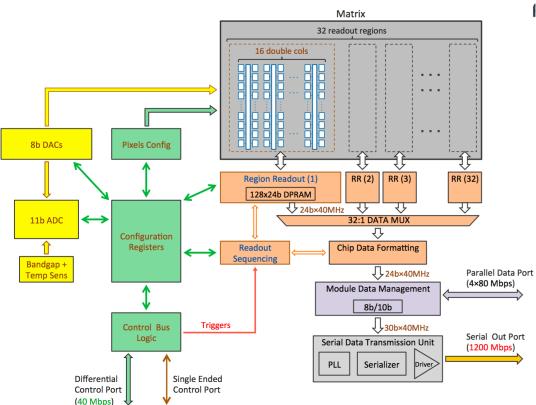


Chip Read-out

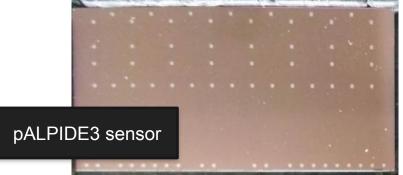
chip dimension 30mm x 15mm

1024 x 514 pixels (pitch ~30um)

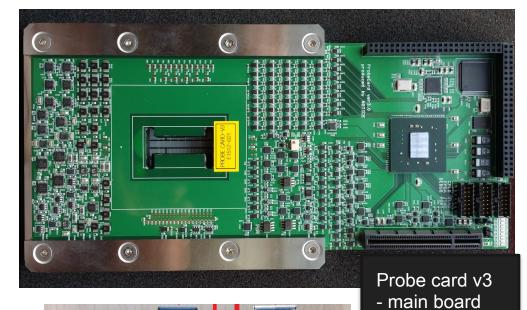




Chip Test setup







Probe – pow

Probe card v3
- power board

Electrical property tests

• probe card firmware has needle contact-test logic implemented.

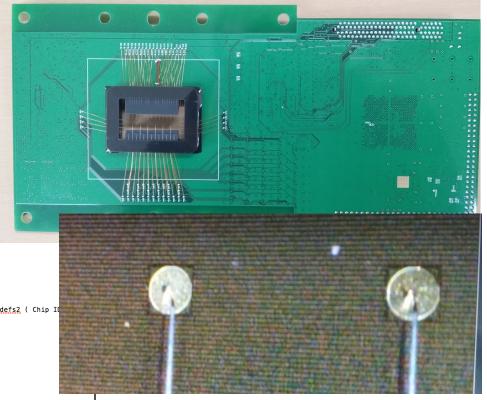
• In full contact, LEDs light up.

```
2. read PWR contact
3. write SIG contact
                                 4. read SIG contact
5. write regulator voltage
                                 6. read regulator current
7. write SHORT combination
                                 8. write operation mode
9. write bidirectional DIR
                                10. write LEDs
11. write readback register
                                12. read readback register
read contact status
                                14. read clock lock status
0. auit
enter commands : 4
DATA = F
MISTRAL 0 = 0
BUSY = \overline{1}
CTRL = 1
CHIPID = 7F
POR DIS = 1
RST_N = 1
HSD\overline{A}TA = 3
MCLK = 3
DACMONV = 1
DACMONI = 1
```



Sensor status test - FIFO

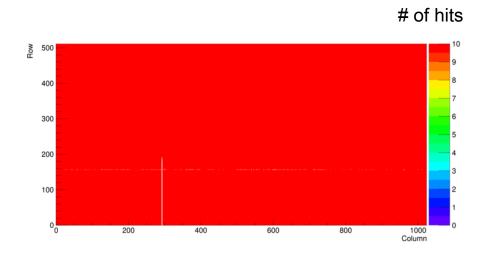
```
[ykwon@Simulation3 pALPIDEfs-software]$ ./runTest FIF0 < log_FIF0_chip_contact.txt &
[ykwon@Simulation3 pALPIDEfs-software]$ [TConfig.cpp] SetDeviceType() Set-up Type: 0 with 1 chips and 1
pALPIDE Test program
Git commit: TestBeamStable_2015-08-06-68-g56d2860-dirty
____
[main.cpp] InitSetup(), Searching for DAQ boards
[TTestSetup::IsDAQBoard] Serial number = 0
[TTestSetup::AddDAQBoard] DAQ board type = 2
[USB.cpp] ConnectUSBDevice(), USB connection established.
[TDagboard::TDAOBoard] TDAOBoard instantiated.
Warning, using DAQBoard2 with ALPIDE-3 firmware
[TTestSetup::AddDAQBoard], created DAQ board:
[TTestSetup::AddDAOBoard], Geographical address: 0
[TTestSetup::AddDAQBoard], Firmware version: 247dfa15
[main.cpp]InitSetup(), found 1 DAQ boards
[TTestSetup::AddDUTs] DUT for chip type 3 added.
 [TTestsetup::GetSetupSummary] Created Setup with 1 DAQ Board(s):
[TTestsetup::GetPlaneSummary] - Plane 0: TDAOBoard 2 ( GeoAdd: 0, firmware Version: 0x247dfa15 ) with TpAlpidefs2 ( Chip I
[TTestSetup::PowerOnBoard] Trying to power on DAQ board 0
[TDagBoard::PowerOn] Voltages off, setting current limits
 [TDagBoard::PowerOn] Switching on voltages...:
 TDagBoard::PowerOnl Reading all ADCs:
 TDagBoard::ReadAllADCs] Read ADC: NTC
[TDagBoard::ReadAllADCs] Read ADC: I(1.8 V Digital) = 0.161133 mA
[TDagBoard::ReadAllADCs] Read ADC: I(1.8 V Output) = 0.241699 mA
 [TDagBoard::ReadAllADCs] Read ADC: I(1.8 V Analog) = 0.241699 mA
 [TpAlpidefs2::GetCMUErrorCounts] Reading register to get CMU Error counts.
 [TpAlpidefs2::ReadRegister] Reading chip 16, register 0x60e
 [TpAlpidefs2::ReadRegister] Value read = 0x0
 [TpAlpidefs2::ReadRegister] Warning, received chip ID 0 instead of 16
[TpAlpidefs2::PrintCMUErrors] No CMU errors found.
[TTestSetup::InitialiseChip] Reading ADCs after chip initialization:
 [TDagBoard::ReadAllADCs] Read ADC: NTC
 [TDagBoard::ReadAllADCs] Read ADC: I(1.8 V Digital) = 0.161133 mA
 [TDagBoard::ReadAllADCs] Read ADC: I(1.8 V Output) = 0.241699 mA
 [TDagBoard::ReadAllADCs] Read ADC: I(1.8 V Analog) = 0.161133 mA
[TpAlpidefs2::ReadRegister] Reading chip 10, register 0x60c
```

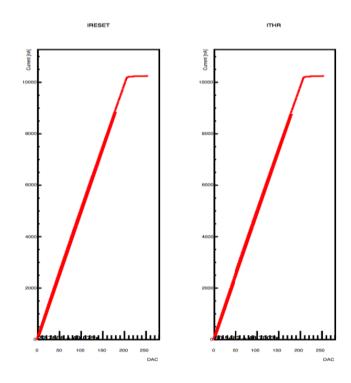


Operation in bypass mode.

Other test functions

- On-chip DAC test (on right)
- Digital/Analog scan (on left)



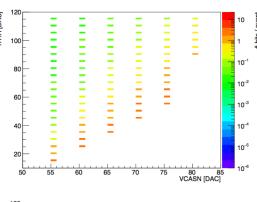


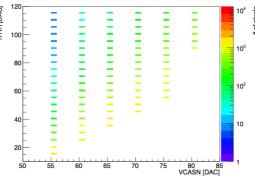
Other test functions

Threshold scan (on right)

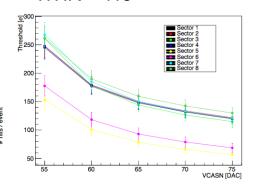
Noise scan

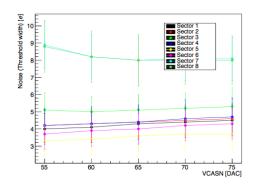
(on left)

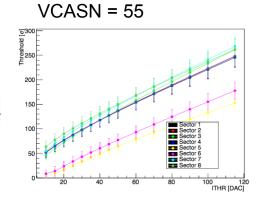


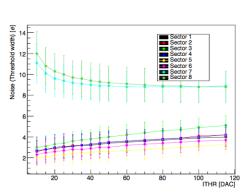


ITHR = 115



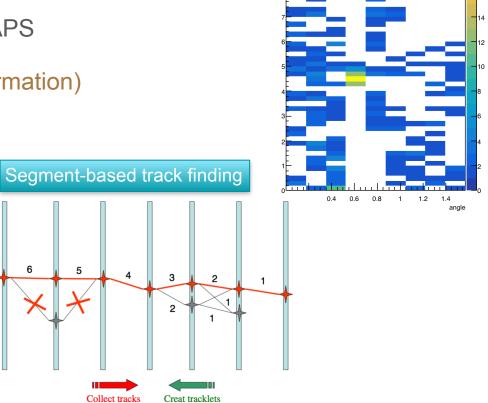






Track/Vertex reconstruction

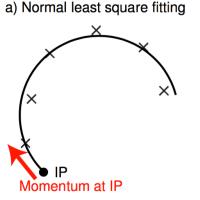
- Current standard procedure for MAPS
- Pattern recognition (Hough transformation)
- Vertex finding
- Track finding (Segment method)
- Track fitting (Kalman filter)
- Vertex fitting



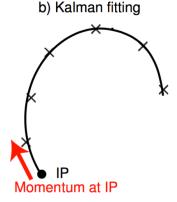
Hough transformation

Track/Vertex reconstruction

- Standard procedure for MAPS
- Pattern recognition (Hough transformation)
- Vertex finding
- Track finding (Cellular automation)
- Track fitting (Kalman filter)
- Vertex fitting



Only one track parameter can be defined



Track parameters are defined par hit

• The success of B-jet tagging highly depends on well-reconstructed tracks of high

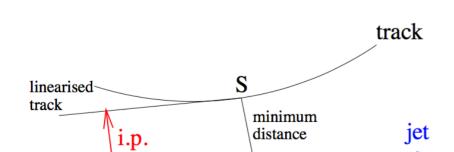
Track Counting

(Impact parameter based method)

purity.

Known methods are:

- Track counting method
- Jet probability method
- Secondary vertex method



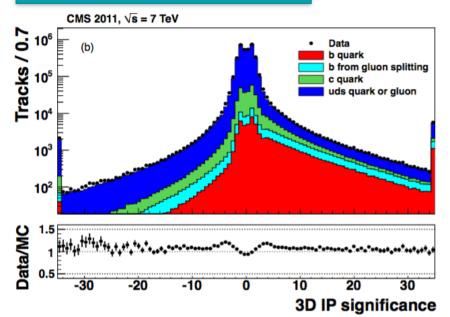
The success of B-jet tagging highly depends on well-reconstructed tracks of high

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Known methods are:

- Track counting method
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- Secondary vertex method

Track Counting (Impact parameter based method)



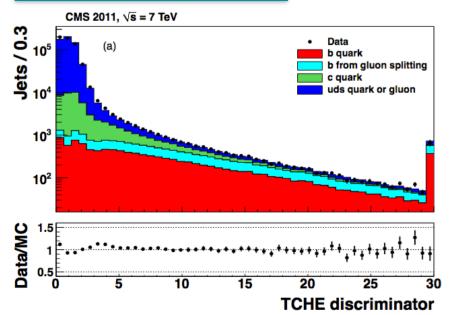
The success of B-jet tagging highly depends on well-reconstructed tracks of high

purity.

Known methods are:

- Track counting method
- Jet probability method
- Secondary vertex method

Track Counting High Efficiency (N=2 differential discriminator)



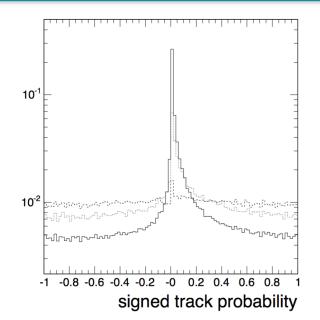
• The success of B-jet tagging highly depends on well-reconstructed tracks of high

purity.

Known methods are:

- Track counting method
- Jet probability method
- Secondary vertex method

Jet probability method (Impact parameter based, inclusive discriminator)



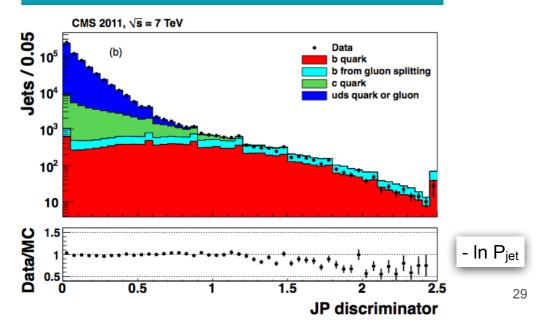
The success of B-jet tagging highly depends on well-reconstructed tracks of high

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Known methods are:

- Track counting method
- Jet probability method
- Secondary vertex method

Jet probability method (Impact parameter based, inclusive discriminator)



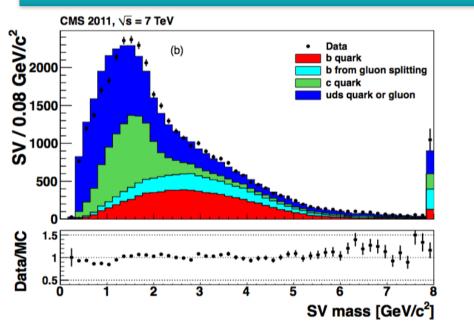
The success of B-jet tagging highly depends on well-reconstructed tracks of high

purity.

Known methods are:

- Track counting method
- Jet probability method
- Secondary vertex method





Future Works

Import/assemble MAPS inner layers from CERN.

Develop data acquisition scheme to be integrate into sPHENIX DAQ.

Evaluate tracking performance with final tracking detector configuration.

Establish b-tagging methods for sPHENIX.

And a lot more work to do...

Thank you!